

Symbiotic stars on Asiago archive plates. II

Ulisse Munari¹ and Rajka Jurdana-Šepić²

¹ Osservatorio Astronomico di Padova, Sede di Asiago, I-36012 Asiago (VI), Italy

² Physics Department, University of Rijeka, Omladinska 14, HR-51000 Rijeka, Croatia

Received 20 November 2001 / Accepted 22 January 2002

Abstract. The Asiago photographic archive has been searched for plates containing the symbiotic stars Hen 2-468, QW Sge, LT Del, V407 Cyg, K 3-9, V335 Vul, FG Ser and Draco C-1. A total of 635 plates imaging the program stars have been found and the brightness estimated using the Henden & Munari (2000) $UBV(RI)_C$ photometric sequences. These historical data have allowed for the first time the determination of the orbital periods of Hen 2-468 (774 days) and QW Sge (390.5 days), a significant improvement in the orbital period of LT Del (465.6 days) and for V407 Cyg an evaluation of the Mira's pulsation period and complex lightcurve shape in the red (R and I bands). Some previously unknown outbursts have been discovered too.

Key words. binaries:symbiotic

1. Introduction

In Paper I (Munari et al. 2001) we presented the first results of the search for plates in the Asiago photographic archive containing symbiotic stars. A total of 602 plates imaging AS 323, Ap 3-1, CM Aql, V1413 Aql, V443 Her, V627 Cas and V919 Sgr were located and the brightness of symbiotic stars estimated at the microscope against the $UBV(RI)_C$ comparison sequences calibrated by Henden & Munari (2000). The effort paid fruitful dividends on these poorly known systems: AS 323 was discovered to be quite probably an eclipsing system with the shortest known orbital period among symbiotic stars ($P=197.6$ days), and CM Aql was found to have a $P=1058$ days orbital period and a remarkable amplitude of the associated reflection/heating effect ($\Delta B \sim 2.2$ mag).

In this second paper of the series we searched the Asiago archive for plates imaging the eight symbiotic stars Hen 2-468, QW Sge, LT Del, V407 Cyg, K 3-9, V335 Vul, FG Ser and Draco C-1. A total of 635 plates were found containing the program stars and their brightness has been again estimated at the microscope against the $UBV(RI)_C$ comparison sequences calibrated by Henden & Munari (2000).

The time scale of variability for symbiotic stars is quite long: the orbital periods range from ~ 1 year up to several decades while rise and decay from an outburst may take anything from a few years to more than a century (cf. Kenyon 1986, Mikolajewska 1996). Such times scales are

generally too long for devoted photometric programs to be carried out by a single Institute, but are instead well handled by those patrol programs that run for at least several decades at some Observatories around the world, one of them being Asiago. To stimulate and facilitate inspection of plates at the various archives in the world, Henden & Munari (2000, 2001, 2002) have so far calibrated accurate and deep $UBV(RI)_C$ sequences around 60 symbiotic stars. The present series of papers applies these sequences to those plates in the Asiago archive found to contain symbiotic stars, with the aim of contributing our data to the effort of reconstructing the longest and most detailed possible historical lightcurves.

2. Results

2.1. Hen 2-468

Discovered on objective-prism plates by Henize (1967) who noted a possible variability, its symbiotic nature was recognized by Carrasco et al. (1983) and Allen (1984) on the basis of optical spectra showing a late M-giant continuum and a rich emission line spectrum including HeII and the 6830 Å symbiotic band. Allen (1974) determined its infrared brightness as $K = 7.96$, $J - K = +1.48$. It was discovered to be a variable star by Margoni and Stagni (1984, their variable #3) that reported for the period 1969–1979 a brightness range $14.0 \leq V \leq 15.0$ and $16.0 \leq B \leq 17.2$. The star however has not yet received a variable star name. Infrared photometry by Munari et al. (1992) gave $K = 8.02$, $J - K = +1.50$, almost identical to Allen (1974), suggesting that the cool giant in

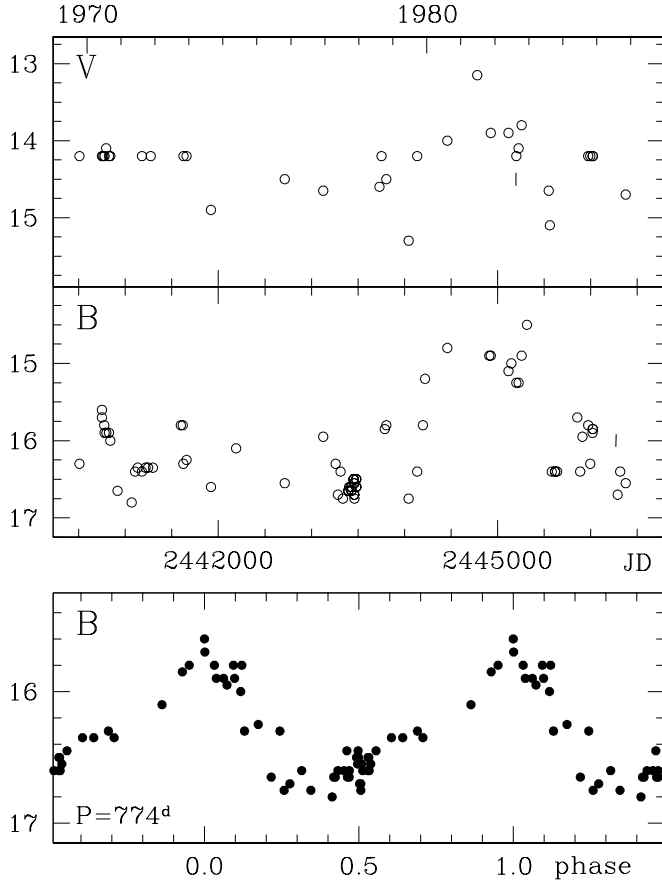


Fig. 1. *B* and *V* lightcurve for Hen 2-468. Vertical bars indicate “fainter than”. *Lower panel:* phase plot of *B* quiescence data (between 2440508 and 2444044) according to Eq. (1).

Table 1. The program symbiotic stars. Equinox J2000 and epoch ~ 2000 coordinates are from Henden & Munari (2000).

	α_{J2000}	δ_{J2000}
Draco C-1	17 19 57.661	+57 50 05.74
FG Ser	18 15 07.121	−00 18 51.96
K 3-9	18 40 24.133	−08 43 57.73
V335 Vul	19 23 14.124	+24 27 40.17
QW Sge	19 45 49.548	+18 36 48.47
LT Del	20 35 57.234	+20 11 27.91
Hen 2-468	20 41 18.989	+34 44 52.52
V407 Cyg	21 02 09.831	+45 46 32.85

He2-468 is not intrinsically variable. Henden and Munari (2000) observed Hen 2-468 in quiescence at $B=16.6$ and $B-V=+1.8$ in 1999, in agreement with the Margoni and Stagni (1984) values.

The Asiago plates (78 *B*, 34 *V* and 5 *I* band) cover the time span between Oct. 1969 and Dec. 1987. The resulting *B* and *V* lightcurves are plotted in Figure 1. On them, Hen 2-468 appears to have been in quiescence up to Oct. 1979, when it entered an outburst phase that lasted until the summer of 1985 when the system returned

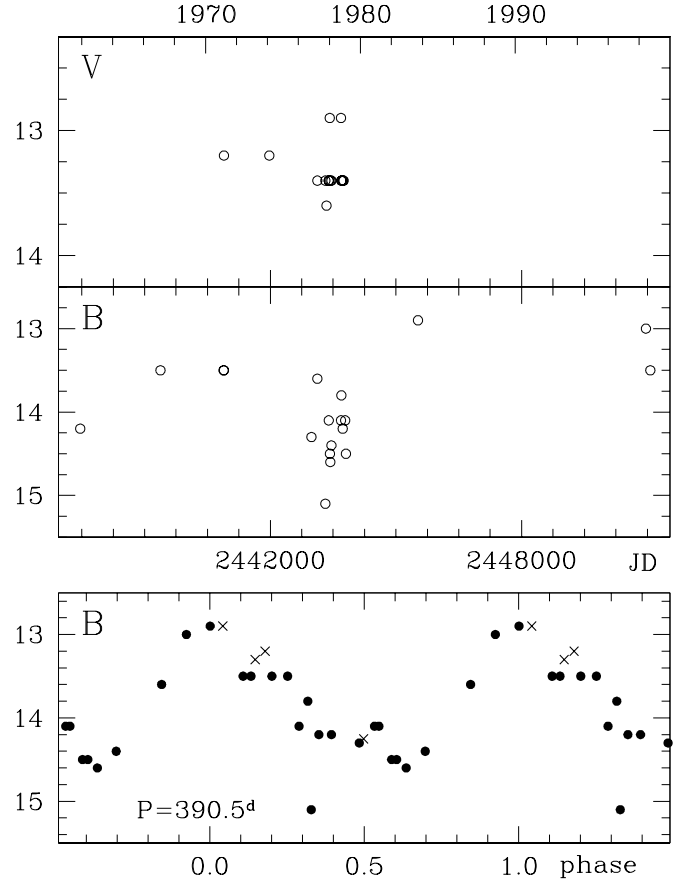


Fig. 2. *B* and *V* data for QW Sge. *Lower panel:* phase plot of *B* data according to Eq. (2). Crosses indicate data from Henden & Munari (2000), Munari & Buson (1991), Palomar DSS-1 and DSS-2.

to mean quiescence brightness. The outburst amplitude was limited, at maximum reaching $\Delta B \sim 1.8$ mag above mean quiescence level. Given the red color in quiescence ($B-V=+1.8$, cf. Table 2), the outburst is barely traceable in the *V* lightcurve dominated by the stable emission of the M giant ($B-V \sim +1.0$ at outburst maximum). This is the first-ever recorded outburst of Hen 2-468.

The *B* quiescence lightcurve of Hen 2-468 looks stable in mean brightness ($\langle B \rangle = 16.3$) but highly variable around it. A period search was performed and revealed a strong 774 day periodicity. The absence of a corresponding modulation in the *V* data and the shape of the phased quiescence *B* lightcurve (presented in the bottom panel of Figure 1) both support the interpretation of the $\Delta B \sim 1.1$ mag variability as a reflection/heating effect, with

$$Max(B) = 2440749 + 774 \times E \quad (1)$$

giving the times of maxima, corresponding to the passage at inferior conjunction of the white dwarf companion to the M giant. The asymmetric placement of the minimum at $\phi \sim 0.35$ could argue in favor of a moderately eccentric orbit. The present one is the first ever determination of the orbital period for Hen 2-468.

2.2. QW Sge

QW Sge (= AS 360) is another symbiotic star that has received scanty attention in the literature. Munari & Buson (1991) already reviewed the latter and discussed the system properties based on IUE, optical and IR observations.

QW Sge has an optical companion 3.5 arcsec to the north, that Munari and Buson classified as an F0 V star with $B=13.59$ and $B-V=+0.45$. Henden and Munari (2000) found different values for it ($B=13.18$ and $B-V=+0.83$), with a large scatter of 0.25 mag between three different measurements (compared to the stability at a few millimag for nearby stars of similar brightness). This clearly indicates that the optical companion is itself a variable star, and this complicates the interpretation of photometry made with moderate or short focus telescopes that are not able to separate QW Sge from the close optical companion (as it is the case for most of the photographic plates in the archives around the world).

The 464 blue plates from the archive of the Sternberg Astronomical Institute in Moscow examined by Kurochkin (1993) suffer from this blending. All his measurements refer to QW Sge and the companion star merged in a single stellar image. Kurochkin's lightcurve covers the period 1898–1990, during which two outbursts took place: one extending from July 1962 to March 1972 with $B=11.5$ at maximum, the other from May 1982 to September 1989 with a much more complex lightcurve and a peak brightness $B=12.0$. In between the combined brightness of QW Sge and its nearby companion remains in the range $12.9 \leq B \leq 13.4$.

Our measurements in Table 2 pertain to quiescence conditions for QW Sge. The favorable focal lengths of the Asiago Schmidt telescopes allow a marginal separation of QW Sge from the companion star. The measurements in Table 2 pertain to QW Sge alone. A few more plates from the Asiago archive were not considered here because bad seeing conditions caused an unrecoverable merging of the two stellar images into a single one.

A period search was performed and a fine periodicity emerged following the ephemeris

$$\text{Max}(B) = 2445528 + 390.5 \times E \quad (2)$$

The Table 2 data are phase plotted in Figure 2. Our measurements are limited in number and non-negligible errors are expected to affect our estimates of the nearly merged stellar pair. To test ephemeris (2) we therefore estimated QW Sge brightness on Palomar DSS-1 and DSS-2 blue plates (JD=2433480 and $B=13.3$, JD=2446326 and $B=12.9$, respectively) and plotted them in Figure 2 as crosses together with single B measurements from Henden and Munari (2000) and Munari and Buson (1991). The agreement of these external data with those from the Asiago plates is excellent over the 5 decades spanned by the data. The lightcurve shape, its amplitude ($\Delta B=1.7$ mag, and a few tenths in V) and the high repeatability over a long period of time suggests an interpretation in term of reflection/heating effect in phase with the orbital

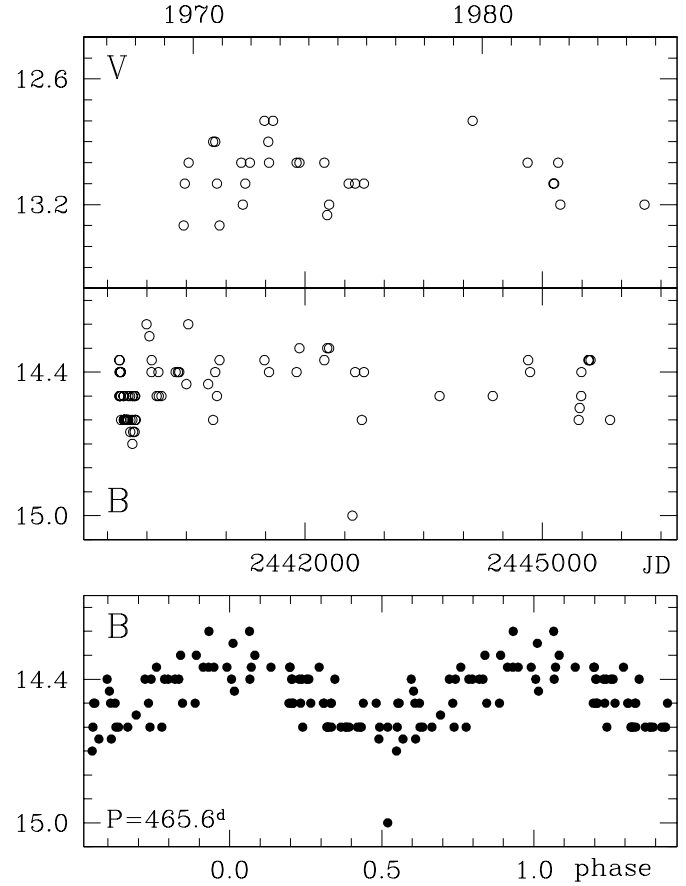


Fig. 3. B and V lightcurve of LT Del. Lower panel: phase plot of B data according to Eq. (3).

motion. The present $390^d.5$ day is the first ever determination of the orbital period of QW Sge.

2.3. LT Del

The history and photometric properties of LT Del up to the early 90ies have already been reviewed by Munari and Buson (1992). The quiescent lightcurve of LT Del displays a strong reflection/heating effect with amplitudes $\Delta U=+1.7$, $\Delta B=0.5$ and $\Delta V=0.2$ mag, that Arkhipova and Noskova (1988) reported to follow the ephemeris $\text{Min} = 2445910 + 488 \times E$, later revised to $\text{Min} = 2445910 + 478.2 \times E$ by Arkhipova et al. (1995). The latter listed $B=14.4$ and $B-V=+1.3$ as mean values for quiescence. Passuello et al. (1994) discovered the only outburst so far recorded for LT Del, with a $\Delta B \sim 1.6$ mag in 1994.

Our lightcurve of LT Del extends from Sept. 1967 to Aug. 1985 (cf. Figure 2), with mean values $B=14.41$ and $B-V=+1.32$ identical to those of Arkhipova et al. (1995) for LT Del in quiescence. A period search revealed a strong periodicity at $465^d.6$, with an amplitude $\Delta B \sim 0.27$ mag and a sinusoidal shape indicative of a reflection/heating effect. The variation follows the ephemeris

$$\text{Max}(B) = 2440493 + 465.6 \times E \quad (3)$$

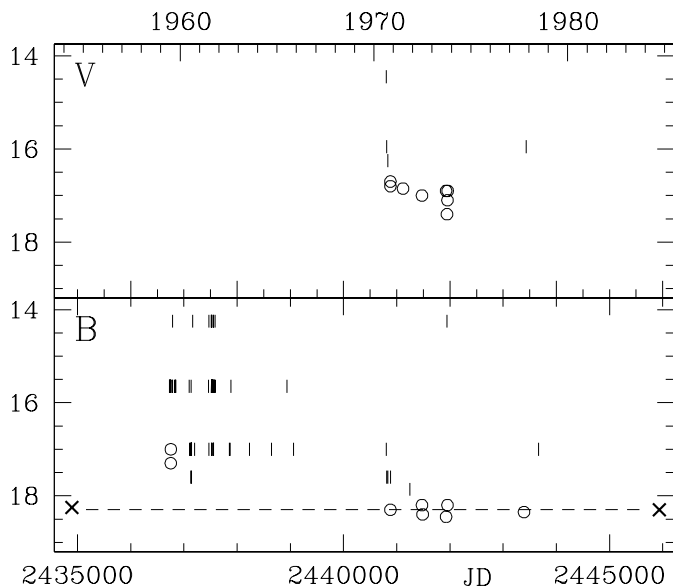


Fig. 4. *B* and *V* data of K 3-9. Vertical bars indicate fainter than. The two crosses indicate the brightness of K 3-9 on Palomar DSS-1 and DSS-2 blue plates, and the dashed line the 1999 quiescence $B=18.3$ level.

The 465^d6 period differs significantly from previous estimates. The 488 days suggested by Arkhipova and Noskova (1988) is definitively ruled out by our data, while the 478.2 days indicated by Arkhipova et al. (1995) performs only marginally better with a high dispersion affecting the folded lightcurve.

2.4. K 3-9

The photometric properties, history and orbital period are unknown for this faint and poorly studied symbiotic star. Given its optical faintness, the scanty investigations were concentrated in the infrared and radio domains where the system is much easier to observe (Iverson and Seaquist 1995). Henden & Munari (2000) report an average $B=18.3$ and $B - V = +1.3$ for 1999.

The lightcurve from Asiago archival plates presented in Table 2 and Figure 4 covers the period from 1959 to 1979 and confirms the optical faintness and the moderately red color of K 3-9. The object has always been close to plate limiting magnitude, however a flat quiescence in the 70ies with $B=18.3$ and $B - V \sim 1.0$ and a brighter phase in 1959 at $B=17.2$ are well established. A ~ 0.5 mag variability affected K 3-9 in *V* with apparently no counterpart in *B*.

Iverson and Seaquist (1995) argued about the possible presence of a Mira in K 3-9 and an ongoing symbiotic nova outburst phase for the WD companion. Symbiotic Miras are normally discovered as such when the WD companion enters a powerful outburst that ionizes and lights-up by several magnitudes the circumstellar material producing a rich emission line forest and a flat blue continuum.

Symbiotic Miras with erupting WD companions show a slow, smooth and monotonic decrease in brightness fol-

lowing outburst maximum. For example, the extremely smooth decline of HM Sge and V1016 Cyg over the last 20 years has been characterized by $\Delta V \sim 0.05$ and $\Delta V \sim 0.03$ mag yr⁻¹, respectively, thus a whole 1 mag for HM Sge and 0.6 mag for V1016 Cyg in 20 years.

On the contrary, K 3-9 has been very stable over the last half century: Table 2 data, Palomar DSS-1 and DSS-2 blue plates ($B=18.25$ on JD=2434895, and $B=18.30$ on JD=2445936) as well as mean values for 1999 from Henden and Munari (2000) all cluster tightly around $B=18.3$, as shown in Figure 4. The absence of any descending trend and the $\Delta B=1.1$ bright phase in 1959 are more reminiscent of classical symbiotic stars with moderate active phases than of symbiotic Miras in outburst. K 3-9 bears differences with symbiotic Miras in outburst also in the spectra: observations included in the multi-epoch spectrophotometric atlas of symbiotic stars by Munari and Zwitter (2001) indicate a moderate ionization of a radiation-bounded circumstellar environment, quite different from the situation in HM Sge, V1016 Cyg and other symbiotic Miras in outburst characterized by firework displays of emission line spectra.

2.5. V407 Cyg

Discovered as Nova Cyg 1936, V407 Cyg attracted interest when (a) Meinunger (1966) reported that the main cause of the object's large variability was the presence of a Mira with a 745 day pulsation period (too long for normal field Miras), and (b) unpublished spectra by different authors described a symbiotic star spectrum appearing from time to time (e.g. Duerbeck 1987). Munari et al. (1990) investigated V407 Cyg lightcurve up to late 80ies, confirming the presence of a Mira and discovering a large modulation of the system mean brightness by $\Delta B \sim 3$ mag. A possible 43 year periodicity was derived for the latter and interpreted as the system orbital period in the framework of the Whitelock (1987) model of variable dust obscuration. However, the lightcurve analyzed by Munari et al. spanned 51 years or just one possible orbital period. Thus the search for blue plates obtained earlier than 1935 with astrographs able to reach $B=16$ would be essential to investigate the secular behaviour of mean brightness and then to confirm the possible 43 year periodicity.

Pulsation periods as long as that of V407 Cyg almost invariably pertain to the central star of OH/IR sources, engulfed by extremely thick dust cocoons that make these objects invisible at blue wavelengths. If the presence of the accreting and outbursting white dwarf companion inhibits the formation of all but an optically thin circumstellar dust shell (Kolotilov et al. 1998), then V407 Cyg would allow an unobstructed view of the central star of an OH/IR source. The dust could partially form and survive only in the shadow cone produced by the Mira itself, which blocks the destroying action of the white dwarf hard radiation field. When, during the orbital motion, the Mira passes at the inferior conjunction and the whole system is

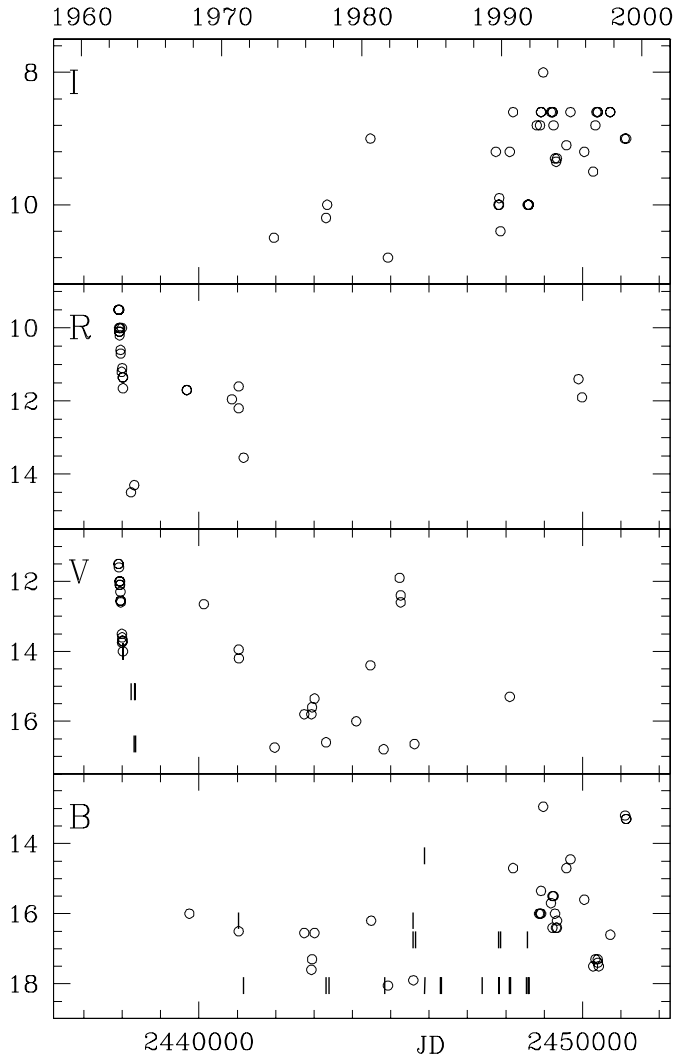


Fig. 5. *B*, *V*, *R* and *I* lightcurves of V407 Cyg. Vertical bars indicate *fainter than*.

seen through the dust cone, the optical pulsation curve is shifted toward fainter magnitudes. In such a framework, the minimum of mean *B* brightness in the early 70s would correspond to passage of the Mira at the inferior conjunction.

A new outburst was discovered in 1994 (Munari et al. 1994), 58 years after the discovery event in 1936. At that time the Mira’s spectrum appeared severely veiled by a hot continuum in the blue and strong lines of Hydrogen, HeI, HeII, [OIII] erupted in emission, settling the classification of V407 Cyg as a symbiotic star.

The results of our searching the Asiago plate archive for V407 Cyg are presented in Figure 5. Plates spanning a 40 year interval have been located. The *B* band data are plotted in a zoomed view in Figure 6 (top panel) and a $\Delta mag = 8$ amplitude sinusoid following the original Meinunger (1966) ephemeris

$$Max(B) = 2429710 + 745 \times E \quad (4)$$

is overplotted for reference. A 43 year, $\Delta mag = 2.1$ amplitude modulation is superimposed to represent the dust

obscuration phase that peaked in 1973. The correspondence between observed points and the sinusoidal approximation is not impressive, for at least two reasons: (a) irregular variability by the accreting white dwarf may contribute significantly to the overall system *B* band brightness (apart from the 1936 and 1994 outbursts), and (b) the Mira in V407 Cyg does not follow regular pulsation cycles characterized by similar and in-phase lightcurves (the VSNET and VSOLJ amateur estimate databanks clearly show quite perturbed lightcurves over the last fifteen years).

The complexity of the Mira pulsations in V407 Cyg is evident when its behaviour at different wavelengths is compared (Figure 6). The lightcurve in the *B* band is only moderately periodic, while the periodicity looks instead almost perfect in our *R* and *I* data. However, the shape and period of the pulsation lightcurve change with the wavelengths. The *R*, *I*, *J* and *K* lightcurves in Figure 6 are computed according to the following ephemerids:

$$Max(R) = 2429710 + 745 \times E \quad (5)$$

$$Max(I) = 2446050 + 747.5 \times E \quad (6)$$

$$Max(J) = 2446100 + 752 \times E \quad (7)$$

$$Max(K) = 2446150 + 755.6 \times E \quad (8)$$

where the original *B*-band ephemeris of Meinunger (1966) was found to be the best performing one for the *R* data and the Kolotilov et al. (1998) ephemeris the best for the *J* data. They are however not satisfactory for *I* and *K* data, for which we determined new periodicities with converging results by different techniques (Fourier and phase dispersion minimization). The apparent increase of the pulsation period (by 1.4%) and shift of phase of maximum (by 13%) going from *R* to *K* wavelengths seems a robust one, as indicated by the poor results that are obtained if the *R* data are phase plotted against Eq. (8) or the *K* data against Eq. (5).

The differences highlighted by Eq.s (5)–(8), whose validity could vanish outside the time-span covered by the data used to derive them, might be related to the highly unusual evolutionary state of the Mira in V407 Cyg, resembling the central star of OH/IR sources. Beating among phenomena characterized by different periodicities and effective temperatures could induce the above shifts in phase and period. Optical depth effects in the Mira’s atmosphere and circumstellar dust envelope could add to the overall picture: viewing the system at different wavelengths means different transparencies of the circumstellar dust and different effective photospheric levels in the stellar atmosphere.

2.6. V335 Vul, FG Ser, Draco C-1

The remaining program stars are only briefly commented upon.

V335 Vul was discovered by Dahlmark (1993) to contain a carbon Mira of 342 day pulsation period. On the basis of marked spectral changes and the emission line

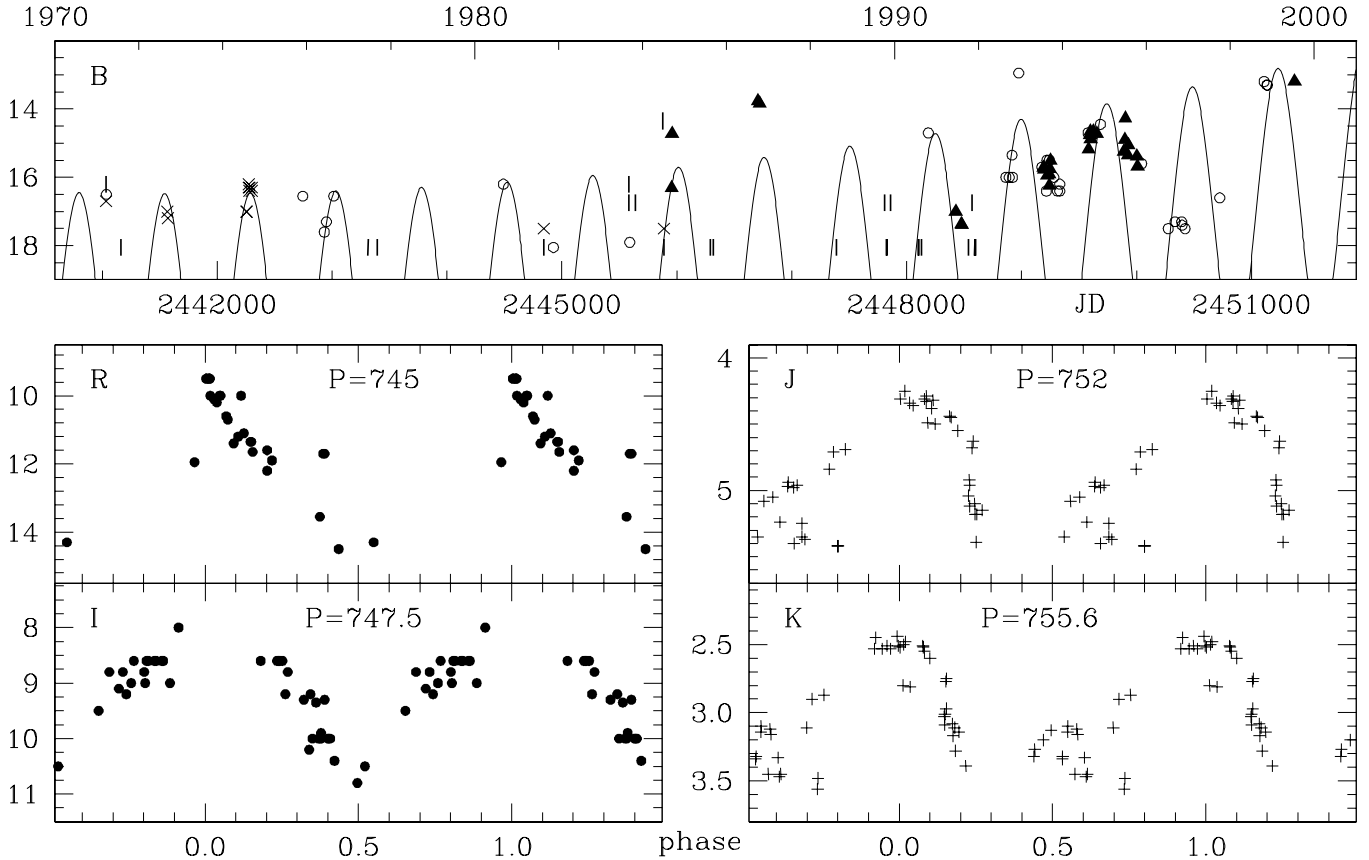


Fig. 6. Upper panel: *B* lightcurve of V407 Cyg with overplotted a sinusoid phased according to Eq. (4) and modulated in mean brightness with a 43 year periodicity. Lower panels: phase plot of *R* and *I* data from Table 2 and *J* and *K* data from Kolotilov et al. (1998) according to Eq.s (5)–(8).

spectrum, Munari et al. (1999) suggested a possible symbiotic nature for this object. Our *B* and *V* data in Table 2 reveal a variability of significant amplitude, but the resulting lightcurve is disappointingly restricted to a narrow range. This is caused by the short time span covered by the plates (a couple of years), the long pulsation period (close to one year), and the seasonal visibility.

The photometric and outburst history of the eclipsing symbiotic star FG Ser has already been reviewed in detail by Munari et al. (1992, 1995) and Kurochkin (1993), and it will not be further commented upon here. Part of the plates here used to derive the magnitude of FG Ser were already investigated by Munari et al., but they are measured again here both to place them on the more accurate Henden & Munari (2000) photometric sequence and to link them with the more recent data reported in Table 2.

Similarly, Draco C-1 plate material prior to 1991 has already been considered by Munari (1991). It has been estimated again here against the better Henden & Munari (2000) comparison sequence, in order to place it on the same scale as the data collected after 1991 and included in Table 2. The star is very close to the limiting magnitude on all plates, and this affects both star detection and brightness estimate. A significant $\Delta I = 0.7$ mag variability is however evident, apparently not much correlated with

B behavior. Apart from a $\Delta B = 1.3$ mag bright phase in 1988, Draco C-1 remained quiescent around $B = 18.4$ over 1987–1996, close to the mean $B = 18.6$ measured in 1999 by Henden & Munari (2000) and the $B = 18.43$ measured in 1981 by Aaronson et al. (1982).

Acknowledgements. RJS wish to thank the hospitality of the Asiago observatory and the Primorsko-Goranska County for financial support.

References

- Allen D.A., 1974, MNRAS 168, 1
- Allen D.A., 1984, Proc.A.S.A. 5, 369
- Aaronson M., Liebert, J., Stocke, J., 1982, Ap.J. 254, 507
- Arkhipova V.P., Noskova, R.I., 1988 SvA Lett 14, 188
- Arkhipova V.P., Ikonnikova, N.P., Noskova, R.I. 1995, PAZh 21, 379
- Carrasco L., Costero R., Serrano P.G. 1983, in *Planetary Nebulae*, Proc. of IAU Symp. 103, D.R.Flower ed., pag. 548
- Dahlmark L., 1993, IBVS 3855
- Duerbeck, H.W. 1987, A Reference Catalogue and Atals of Galactic Novae, Reidel, Dordrecht
- Henden A.A., Munari U., 2000, A&AS 143, 343
- Henden A.A., Munari U., 2001, A&A 372, 145
- Henden A.A., Munari U., 2002, A&A to be submitted
- Henize K.G. 1967, ApJS 14, 125

- Iverson R.J., Seaquist E.R. 1995, MNRAS 272, 878
 Kenyon 1986, *The Symbiotic Stars*, Cambridge University Press
 Kolotilov E.A., Munari U., Popova A.A., Tatarnikov A.M., Shenavrin V.I., Yudin B.F. 1998, *Astron. Lett.* 24, 451
 Kurochkin N.E. 1993, *Astron.Astrophys.Transactions* 3, 295
 Margoni R., Stagni R. 1984, *A&AS* 56, 87
 Meinunger L., 1966, *Mitt.Veranderl.Sterne* 3, 111
 Mikolajewska J. 1996, *Physical Processes in Symbiotic Binaries and Related Objects*, editor, Polish Academy of Sciences, Warsaw
 Munari U., 1991, *A&A* 251, 103
 Munari U., Buson L.M. 1991, *A&A* 249, 141
 Munari U., Buson L.M. 1992, *A&A* 255, 158
 Munari U., Zwitter T. 2002, *A&A* in press
 Munari U., Bragaglia A., Guarneri M.D., Sostero G., Lepardo A., Yudin B.F., 1994, *IAU Circ* 6049
 Munari U., Jurdana-Šepić R., Moro D. 2001, *A&A* 370, 503 (Paper I)
 Munari U., Margoni R., Stagni R. 1990, MNRAS 242, 653
 Munari U., Tomov T., Rejkuba M., 1999, *Inf.Bull.Var.Stars* 4668
 Munari U., Rejkuba M., Mattei J., Hazen M., Luthardt R., Yudin B.F. 1997, *A&A* 323, 113
 Munari U., Yudin B.F., Taranova O.G., Massone G., Marang F., Roberts G., Winkler H., Whitelock P.A. 1992a, *A&AS* 93, 383
 Munari U., Yudin B.F., Kolotilov E., Gilmore A. 1995, *AJ* 109, 1740
 Munari U., Whitelock P.A., Gilmore A.C., Blanco C., Massone G., Schmeer P.K. 1992b, *AJ* 104, 262
 Passuello R., Saccavino S., Munari U. 1994, *IAU Circ* 6065
 Whitelock P.A., 1987 *PASP* 99, 573

Table 2. The $UBV(RI)_C$ magnitudes of the program stars estimated on the Asiago archive plates. The date is given in the year/month/day format, the JD is heliocentric and the magnitude is estimated in steps of 0.05 mag.

date	HJD	mag	date	HJD	mag	date	HJD	mag
K 3-9			K 3-9			QW Sge		
1959 06 08	2436727.505	B>15.65	1964 09 07	2438646.404	B>17.00	1978 08 08	2443729.477	B=14.20
1959 06 10	2436730.470	B>15.65	1965 06 27	2438939.469	B>15.65	1978 09 01	2443753.366	V=13.40
1959 06 11	2436730.506	B>17.00	1965 10 24	2439058.259	B>17.00	1978 10 07	2443789.368	B=14.10
1959 06 11	2436731.499	B>15.65	1970 08 03	2440802.384	B>17.00	1978 10 23	2443805.303	B=14.50
1959 06 26	2436746.423	B>15.65	1970 08 03	2440802.391	V>14.45	1983 07 12	2445528.473	B=12.90
1959 06 27	2436747.402	B>15.65	1970 08 10	2440809.432	B>17.60	1998 06 02	2450966.550	B=13.00
1959 06 27	2436747.497	B>15.65	1970 08 10	2440809.445	V>15.95	1988 09 17	2451074.414	B=13.50
1959 07 01	2436751.475	B>15.65	1970 09 06	2440836.358	V>16.25			
1959 07 02	2436752.470	B=17.30	1970 09 06	2440836.371	B>17.60	LT Del		
1959 07 03	2436753.478	B=17.00	1970 10 21	2440881.268	B>17.60			
1959 07 09	2436759.423	B>17.00	1970 10 21	2440881.287	V=16.80	1967 09 06	2439740.348	B=14.60
1959 07 11	2436761.429	B>17.00	1970 10 22	2440882.237	V=16.70	1967 09 10	2439744.360	B=14.60
1959 07 12	2436762.448	B>17.00	1970 10 22	2440882.249	B=18.30	1967 09 23	2439757.283	B=14.60
1959 08 01	2436782.366	B>15.65	1971 06 15	2441118.485	V=16.85	1967 09 27	2439761.371	B=14.60
1959 08 03	2436784.358	B>14.25	1971 10 20	2441245.237	I=15.65	1967 09 29	2439763.367	B=14.60
1959 08 07	2436788.360	B>15.65	1971 10 20	2441245.258	B>17.86	1967 06 12	2439653.556	B=14.35
1959 08 24	2436805.332	B>17.00	1972 06 06	2441475.479	B=18.20	1967 06 13	2439654.521	B=14.35
1959 08 25	2436806.335	B>17.00	1972 06 06	2441475.493	V=17.00	1967 06 14	2439655.525	B=14.50
1959 08 26	2436807.389	B>17.00	1972 06 18	2441486.516	B=18.40	1967 06 15	2439656.512	B=14.40
1959 09 08	2436820.339	B>15.65	1973 09 01	2441927.348	B=18.45	1967 06 10	2439652.501	B=14.50
1959 09 22	2436834.280	B>15.65	1973 09 01	2441927.363	V=16.90	1967 06 15	2439657.472	B=14.40
1959 10 01	2436843.261	B>15.65	1973 09 19	2441945.324	V=17.40	1967 06 16	2439658.491	B=14.50
1959 10 02	2436844.281	B>17.00	1973 09 19	2441945.339	B>14.25	1967 06 26	2439668.386	B=14.40
1959 10 04	2436846.255	B>15.65	1973 09 27	2441953.276	R>15.75	1967 06 28	2439670.378	B=14.50
1960 06 16	2437101.509	B>15.65	1973 09 27	2441953.294	V=17.10	1967 06 30	2439672.442	B=14.40
1960 06 17	2437103.481	B>17.00	1973 09 27	2441953.310	B=18.20	1967 06 31	2439673.495	B=14.60
1960 07 04	2437119.525	B>17.00	1973 09 28	2441954.273	R=15.80	1967 08 15	2439717.506	B=14.60
1960 07 13	2437129.409	B>17.60	1973 09 28	2441954.288	R=15.60	1967 08 02	2439705.479	B=14.50
1960 07 14	2437130.417	B>17.00	1973 10 02	2441958.269	V=16.90	1967 08 03	2439706.426	B=14.50
1960 07 17	2437133.494	B>15.65	1977 09 06	2443393.317	I=14.40	1967 08 07	2439710.389	B=14.60
1960 07 19	2437135.485	B>17.00	1977 09 06	2443393.341	B=18.35	1967 08 08	2439711.404	B=14.60
1960 07 23	2437139.434	B>17.60	1977 10 16	2443433.316	I>13.20	1967 08 09	2439712.371	B=14.60
1960 07 24	2437140.438	B>17.00	1977 10 16	2443433.336	V>15.95	1967 08 10	2439713.441	B=14.60
1960 07 25	2437141.380	B>17.00	1978 06 05	2443664.548	I=15.50	1967 08 29	2439732.321	B=14.60
1960 07 29	2437145.484	B>17.00	1978 06 05	2443664.571	B>17.00	1967 09 05	2439739.315	B=14.60
1960 08 20	2437167.366	B>14.25	1978 08 11	2443732.456	I=13.40	1967 10 02	2439766.405	B=14.50
1960 09 22	2437200.322	B>17.00				1967 10 22	2439786.261	B=14.50
1961 06 14	2437464.523	B>15.65	QW Sge			1967 10 26	2439790.314	B=14.65
1961 06 17	2437467.515	B>17.00	1961 06 15	2437465.560	B=14.20	1967 10 27	2439791.262	B=14.60
1961 06 18	2437468.520	B>14.25	1966 09 09	2439378.347	B=13.50	1967 11 22	2439817.214	B=14.70
1961 08 02	2437514.443	B>14.25	1970 10 24	2440884.244	B=13.50	1967 11 23	2439818.219	B=14.60
1961 08 04	2437516.437	B>15.65	1970 11 03	2440894.284	V=13.20	1967 11 24	2439819.214	B=14.50
1961 08 05	2437517.415	B>17.00	1970 11 03	2440894.295	B=13.50	1967 11 26	2439821.296	B=14.50
1961 08 06	2437518.415	B>17.00	1973 10 23	2441979.248	V=13.20	1967 12 02	2439827.243	B=14.65
1961 08 07	2437519.425	B>15.65	1976 07 23	2442983.467	B=14.30	1967 12 20	2439845.237	B=14.50
1961 08 08	2437520.421	B>14.25	1976 12 11	2443124.219	B=13.60	1967 12 21	2439846.236	B=14.65
1961 08 09	2437521.442	B>15.65	1976 12 11	2443124.238	V=13.40	1967 12 27	2439852.261	B=14.50
1961 08 11	2437523.468	B>14.25	1976 12 13	2443126.241	R=12.50	1967 12 28	2439853.239	B=14.60
1961 08 12	2437524.472	B>15.65	1977 06 18	2443313.413	B=15.10	1968 01 01	2439857.245	B=14.60
1961 08 17	2437529.428	B>15.65	1977 06 18	2443313.428	V=13.40	1968 05 19	2439995.636	B=14.20
1961 08 18	2437530.449	B>15.65	1977 06 18	2443313.430	R=12.00	1968 06 25	2440032.547	B=14.25
1961 08 29	2437541.355	B>15.65	1977 06 18	2443313.455	I=11.45	1968 07 23	2440060.512	B=14.35
1961 08 31	2437543.386	B>15.65	1977 06 18	2443313.455	I=11.45	1968 07 20	2440058.502	B=14.40
1961 09 01	2437544.383	B>15.65	1977 07 17	2443342.496	V=13.60	1968 09 25	2440124.506	B=14.50
1961 09 03	2437546.338	B>17.00	1977 09 06	2443393.363	B=14.10	1968 10 15	2440145.346	B=14.40
1961 09 04	2437547.397	B>14.25	1977 09 06	2443393.380	V=13.40	1968 10 21	2440151.429	B=14.50
1961 09 06	2437549.388	B>17.00	1977 09 11	2443398.340	V=13.40	1968 11 22	2440183.291	B=14.50
1961 09 07	2437550.346	B>15.65	1977 10 03	2443420.359	V=12.90	1969 05 22	2440363.557	B=14.40
1961 09 09	2437552.361	B>15.65	1977 10 04	2443421.355	B=14.50	1969 06 20	2440393.490	B=14.40
1961 09 15	2437558.370	B>14.25	1977 10 16	2443433.356	V=13.40	1969 07 06	2440409.472	B=14.40
1961 09 16	2437559.359	B>17.00	1977 10 16	2443433.373	B=14.60	1969 09 01	2440466.330	V=13.30
1961 09 17	2437560.404	B>15.65	1977 11 09	2443457.298	B=14.40	1969 09 15	2440480.402	V=13.10
1961 10 02	2437575.342	B>15.65	1977 11 10	2443458.317	V=13.40	1969 10 05	2440500.295	B=14.45
1961 10 05	2437578.327	B>15.65	1978 06 28	2443688.463	B=14.10	1969 10 28	2440523.244	B=14.20
1961 10 09	2437582.313	B>14.25	1978 06 28	2443688.479	V=12.90	1969 11 01	2440527.284	V=13.00
1961 10 10	2437583.327	B>15.65	1978 07 09	2443699.434	V=13.40	1970 07 06	2440774.486	B=14.45
1962 07 08	2437854.488	B>17.00	1978 07 09	2443699.485	V=13.40	1970 09 07	2440836.525	V=12.90
1962 07 24	2437870.422	B>17.00	1978 07 09	2443699.501	B=13.80	1970 09 07	2440836.538	B=14.60
1962 08 06	2437883.431	B>15.65	1978 08 02	2443723.389	V=13.40	1970 10 04	2440864.451	V=12.90
1963 07 19	2438230.463	B>17.00	1978 08 08	2443729.461	V=13.40	1970 10 04	2440864.465	B=14.40

Table 2. (*continues*)

<i>date</i>	<i>HJD</i>	<i>mag</i>	<i>date</i>	<i>HJD</i>	<i>mag</i>	<i>date</i>	<i>HJD</i>	<i>mag</i>
LT Del			Hen 2-468			Hen 2-468		
1970 10 26	2440886.353	V=13.10	1971 06 02	2441105.423	I=11.45	1982 09 14	2445227.396	B=15.25
1970 10 26	2440886.372	B=14.50	1971 06 02	2441105.489	B=16.40	1982 10 15	2445258.375	V=13.80
1970 11 27	2440918.304	V=13.30	1971 07 01	2441133.519	B=16.35	1982 10 16	2445259.378	B=14.90
1970 11 27	2440918.318	B=14.35	1971 08 14	2441178.439	V=14.20	1982 12 11	2445315.325	B=14.50
1971 08 29	2441193.453	V=13.00	1971 08 14	2441178.453	B=16.40	1983 08 04	2445551.441	V=14.65
1971 09 18	2441213.391	V=13.20	1971 09 22	2441217.337	B=16.35	1983 08 15	2445562.440	V=15.10
1971 10 18	2441243.407	V=13.10	1971 10 20	2441245.385	B=16.35	1983 09 05	2445583.400	B=16.40
1971 12 17	2441303.245	V=13.00	1971 11 16	2441272.218	V=14.20	1983 10 09	2445617.360	B=16.40
1972 06 19	2441487.517	V=12.80	1971 12 10	2441296.269	I=11.45	1983 10 12	2445620.460	B=16.40
1972 06 18	2441487.502	B=14.35	1971 12 10	2441296.289	B=16.35	1983 11 01	2445640.412	B=16.40
1972 08 04	2441534.456	V=12.90	1972 10 04	2441595.367	B=15.80	1984 06 06	2445857.546	B=15.70
1972 08 15	2441545.439	V=13.00	1972 10 25	2441616.250	B=15.80	1984 07 07	2445888.550	B=16.40
1972 08 15	2441545.450	B=14.40	1972 11 01	2441623.280	B=16.30	1984 07 30	2445912.476	B=15.95
1972 10 04	2441595.297	V=12.80	1972 11 02	2441624.282	V=14.20	1984 09 30	2445974.425	V=14.20
1973 09 02	2441928.446	B=14.30	1972 12 05	2441657.256	B=16.25	1984 09 30	2445974.440	B=15.80
1973 09 02	2441928.442	V=13.00	1972 12 06	2441658.259	V=14.20	1984 10 23	2445997.412	V=14.20
1973 07 29	2441892.522	V=13.00	1973 08 24	2441919.479	B=16.60	1984 10 23	2445997.428	B=16.30
1973 07 29	2441892.535	B=14.40	1973 08 24	2441919.491	V=14.90	1984 11 17	2446022.293	B=15.85
1974 07 15	2442243.515	V=13.00	1974 05 22	2442190.464	B=16.10	1984 11 17	2446022.312	V=14.20
1974 07 14	2442243.500	B=14.35	1975 10 27	2442713.303	B=16.55	1984 11 17	2446022.332	B=15.90
1974 08 20	2442280.425	V=13.25	1975 10 27	2442713.315	V=14.50	1984 11 20	2446025.331	B=15.85
1974 08 20	2442280.438	B=14.30	1976 12 14	2443127.267	B=15.95	1984 11 20	2446025.346	V=14.20
1974 09 13	2442304.368	B=14.30	1976 12 14	2443127.283	V=14.65	1985 07 27	2446273.506	B>16.00
1974 09 13	2442304.390	V=13.20	1977 04 26	2443259.569	B=16.30	1985 08 13	2446290.507	B=16.70
1975 05 19	2442551.590	V=13.10	1977 05 21	2443284.567	B=16.70	1985 09 09	2446318.364	B=16.40
1975 07 03	2442597.480	B=15.00	1977 06 19	2443314.473	B=16.40	1985 11 08	2446378.318	B=16.55
1975 08 08	2442633.364	B=14.40	1977 07 13	2443337.522	B=16.75	1985 11 08	2446378.340	V=14.70
1975 08 08	2442633.389	V=13.10	1977 09 07	2443394.366	B=16.65	1987 07 23	2447000.450	I=11.45
1975 10 31	2442717.348	B=14.60	1977 09 11	2443398.379	B=16.65	1987 10 18	2447087.319	I=11.40
1975 11 26	2442743.271	B=14.40	1977 09 18	2443405.411	B=16.60	1987 12 19	2447149.335	I=11.60
1975 11 26	2442743.283	V=13.10	1977 10 03	2443420.379	B=16.60			
1978 07 10	2443699.523	B=14.50	1977 10 12	2443429.304	B=16.65	V335 Vul		
1979 08 31	2444117.410	V=12.80	1977 10 16	2443433.398	B=16.65			
1980 05 13	2444372.548	B=14.50	1977 10 16	2443433.490	B=16.60	1984 07 30	2445912.408	B=15.95
1981 07 27	2444813.476	V=13.00	1977 11 04	2443452.052	B=16.50	1984 07 30	2445912.417	B=15.95
1981 08 03	2444820.471	B=14.20	1977 11 05	2443453.299	B=16.50	1984 07 30	2445912.429	V=13.00
1981 08 27	2444844.491	B=14.40	1977 11 06	2443454.395	B=16.55	1984 07 31	2445913.451	B=16.20
1982 06 20	2445140.505	V=13.10	1977 11 08	2443456.393	B=16.50	1984 08 04	2445917.403	V=13.20
1982 06 29	2445149.524	V=13.10	1977 11 11	2443459.303	B=16.70	1984 08 04	2445917.421	B=16.10
1982 08 18	2445199.509	V=13.00	1977 11 14	2443462.346	B=16.75	1984 08 29	2445942.437	V>10.45
1982 09 13	2445226.453	V=13.20	1977 11 14	2443462.399	B=16.70	1984 08 30	2445943.460	V=12.80
1983 05 17	2445471.546	B=14.55	1977 11 16	2443464.401	B=16.55	1984 08 30	2445943.477	B>14.00
1983 05 03	2445458.496	B=14.60	1977 12 02	2443480.226	B=16.60	1984 08 31	2445944.381	B>15.15
1983 06 05	2445490.542	B=14.50	1977 12 02	2443480.301	B=16.50	1984 09 01	2445945.364	V=12.60
1983 06 09	2445494.542	B=14.40	1977 12 04	2443482.228	B=16.50	1984 09 01	2445945.382	B=16.10
1983 09 04	2445582.409	B=14.35	1977 12 05	2443483.270	B=16.60	1984 09 01	2445945.391	V=12.60
1983 09 12	2445590.423	B=14.35	1978 08 12	2443732.555	V=14.60	1984 10 30	2446004.370	V=11.80
1983 10 02	2445610.361	B=14.35	1978 09 01	2443753.473	V=14.20	1984 10 30	2446004.381	B=15.85
1984 06 05	2445856.536	B=14.60	1978 10 07	2443789.387	B=15.85	1985 04 17	2446172.563	V=13.10
1985 08 13	2446291.426	V=13.20	1978 10 23	2443805.484	V=14.50	1985 06 18	2446234.529	B=15.85
			1978 10 24	2443806.414	B=15.80	1985 07 11	2446258.453	B=16.60
Hen 2-468			1979 06 19	2444044.491	B=16.75	1985 07 11	2446258.469	V=12.75
1969 10 13	2440508.340	B=16.30	1979 06 20	2444044.508	V=15.30	1985 07 22	2446269.435	B=16.40
1969 10 13	2440508.351	V=14.20	1979 09 19	2444136.367	V=14.20	1985 08 12	2446290.423	B=16.00
1970 06 11	2440748.536	B=15.60	1979 09 19	2444136.467	B=16.40	1985 08 19	2446297.471	B=16.00
1970 06 11	2440748.589	V=14.20	1979 11 20	2444198.329	B=15.80	1985 09 09	2446318.394	B=16.00
1970 06 12	2440749.554	B=15.70	1979 12 13	2444221.330	B=15.20	1986 07 10	2446622.488	V=12.60
1970 06 25	2440763.473	V=14.20	1980 08 10	2444461.557	B=14.80	1986 07 11	2446622.504	B=16.15
1970 07 05	2440773.470	B=15.80	1980 08 10	2444461.572	V=14.00	1986 08 01	2446644.424	B=16.00
1970 07 11	2440778.517	B=15.90	1981 06 27	2444782.516	V=13.15			
1970 07 11	2440778.533	V=14.20	1981 11 03	2444912.363	B=14.90	Draco C-1		
1970 07 26	2440794.498	V=14.10	1981 11 19	2444928.278	B=14.90			
1970 07 28	2440796.443	B=15.90	1981 11 19	2444928.301	V=13.90	1987 07 24	2447001.426	B=18.30
1970 08 25	2440824.406	B=15.90	1982 05 29	2445118.541	B=15.10	1987 07 27	2447003.506	I=15.50
1970 08 25	2440824.419	V=14.20	1982 05 29	2445118.573	V=13.90	1988 07 28	2447370.528	B=17.70
1970 09 09	2440839.415	B=16.00	1982 06 28	2445148.536	B=15.00	1988 07 28	2447370.533	B=18.00
1970 09 09	2440839.427	V=14.20	1982 08 18	2445199.546	V>14.50	1988 08 14	2447388.426	B>18.60
1970 11 25	2440916.276	B=16.65	1982 08 19	2445201.368	B=15.25	1989 05 06	2447652.530	I>15.70
1971 04 27	2441068.549	B=16.80	1982 08 19	2445201.389	V=14.20	1989 05 29	2447675.556	I=15.10
			1982 09 14	2445227.375	V=14.10	1989 06 10	2447687.550	B=18.60

date		HJD	mag	date		HJD	mag	date		HJD	mag
Draco C-1				V407 Cyg				V407 Cyg			
1989 06 10	2447687.587	I=14.80		1963 07 18	2438229.499	V>15.15		1990 07 28	2448100.527	B>18.05	
1989 08 03	2447742.417	I=14.80		1963 07 19	2438229.505	R=14.50		1990 07 29	2448101.537	V=15.30	
1989 08 09	2447748.398	B>18.60		1963 10 08	2438311.302	V>16.65		1990 08 23	2448127.494	B>18.05	
1989 09 04	2447774.386	I>15.54		1963 10 11	2438314.315	R=14.30		1990 10 22	2448187.333	B=14.70	
1989 09 04	2447774.423	B>17.70		1963 10 18	2438321.308	V>15.15		1990 10 22	2448187.368	I= 8.60	
1990 07 20	2448093.481	B>18.60		1963 11 08	2438342.265	V>15.15		1991 10 09	2448539.469	B>18.05	
1990 07 21	2448093.507	V=17.00		1963 11 17	2438351.244	V>16.65		1991 11 07	2448568.386	B>16.75	
1990 07 28	2448101.401	B>16.95		1967 07 10	2439681.537	R=11.70		1991 11 07	2448568.414	I=10.00	
1990 08 18	2448122.409	B=18.30		1967 07 13	2439685.480	R=11.70		1991 11 30	2448591.411	B>18.05	
1990 09 18	2448153.382	B>14.35		1967 09 17	2439750.539	B=16.00		1991 11 30	2448591.447	I=10.00	
1990 10 14	2448179.291	I>15.60		1968 09 27	2440127.364	V=12.65		1991 12 02	2448593.416	B>18.05	
1990 10 14	2448179.324	B>18.60		1970 09 29	2440859.428	R=11.95		1991 12 02	2448593.446	I=10.00	
1993 05 21	2449129.410	B=18.40		1971 03 25	2441035.620	B>16.20		1991 12 06	2448597.313	B>18.05	
1993 05 21	2449129.440	I=15.60		1971 03 25	2441035.626	B=16.50		1991 12 06	2448597.341	I=10.00	
1993 07 22	2449191.415	B=18.45		1971 03 25	2441035.636	R=11.60		1992 07 02	2448806.496	I= 8.80	
1993 08 13	2449213.494	B>18.60		1971 03 25	2441035.637	V=13.95		1992 08 27	2448862.458	B=16.00	
1993 08 16	2449216.442	I=15.60		1971 03 25	2441035.652	R=12.20		1992 09 25	2448891.475	B=16.00	
1995 05 04	2449841.529	B>16.95		1971 03 30	2441040.649	V=14.20		1992 09 26	2448891.504	I= 8.80	
1995 08 03	2449933.391	B>16.95		1971 07 31	2441163.540	B>18.05		1992 10 20	2448916.461	B=15.35	
1995 08 22	2449952.409	B=18.35		1971 07 31	2441163.586	R=13.55		1992 10 21	2448916.532	I= 8.60	
1995 08 22	2449952.445	I>14.35		1973 09 28	2441954.443	U>16.65		1992 10 24	2448920.372	B=16.00	
1996 06 19	2450254.489	B=18.50		1973 09 28	2441954.470	I=10.50		1992 10 24	2448920.404	I= 8.60	
1996 06 20	2450254.508	I>14.35		1973 10 18	2441974.283	U>18.05		1992 12 18	2448975.291	B=12.95	
1996 09 07	2450334.358	B=18.40		1973 10 18	2441974.300	V=16.75		1992 12 18	2448975.322	I= 7.00	
1996 09 07	2450334.386	I>14.35		1975 11 28	2442745.280	B=16.55		1993 07 06	2449175.497	B=15.70	
1997 05 30	2450598.564	B>16.95		1975 11 28	2442745.298	V=15.80		1993 07 07	2449175.509	I= 8.60	
1997 07 30	2450660.449	B>17.70		1976 06 03	2442932.540	B=17.60		1993 08 15	2449215.457	I= 8.60	
				1976 06 03	2442932.558	V=15.80		1993 08 15	2449215.485	B=16.40	</

Table 2. (*continues*)

<i>date</i>	<i>HJD</i>	<i>mag</i>
FG Ser		
1969 07 16	2440419.487	B=12.00
1972 07 16	2441515.382	B=14.50
1972 07 16	2441515.457	I= 9.30
1972 08 08	2441538.399	B=14.40
1972 08 08	2441538.417	I= 8.80
1975 05 02	2442535.493	B=13.20
1977 07 22	2443347.467	B=14.15
1977 10 03	2443420.268	B=14.30
1987 07 24	2447001.460	B=13.60
1987 07 26	2447003.481	I= 8.80
1988 07 04	2447347.442	B=11.00
1988 08 09	2447383.431	B=10.50
1988 08 12	2447386.366	B=10.80
1988 09 17	2447422.357	B=11.40
1988 10 15	2447450.326	B=11.95
1989 05 29	2447675.526	B=13.10
1989 10 04	2447804.336	B=11.00
1990 06 19	2448061.539	B=12.00
1990 07 21	2448094.414	B=12.30
1990 08 20	2448124.395	B=12.30
1992 07 03	2448807.468	V=11.20
1992 09 25	2448891.370	B=12.90
1992 09 25	2448891.393	V=11.20
1993 05 26	2449133.547	V=11.70
1993 05 26	2449133.568	B=13.90
1993 06 17	2449156.436	U=13.00
1993 06 17	2449156.466	B=13.30
1993 08 21	2449221.364	B=12.80
1993 08 21	2449221.387	V=11.35
1995 05 04	2449841.583	V=11.35